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ON THE DISTRIBUTION OF MINERAL SALT IN AUTOGENOUS BONE GRAFTS IN MAN

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In spite of the extensive literature on bone grafts—a bibliography by *Chase & Herndon* lists 855 papers published up to 1955—and the intensive research conducted in the past decade, the central question of how osteogenesis is induced by a graft still remains to be answered. The majority of the investigations reported have comprised animal experiments and one must be cautious about drawing analogies between these and clinical situations.

In clinical work, the incorporation of a bone graft is generally followed with conventional roentgenography, which gives only a rough anatomical picture of the extent of mineralization. This makes it desirable to obtain a picture of the microscopic distribution of bone salts in the graft. The pattern of mineralization can be followed both quantitatively and qualitatively with microradiography, which has been developed by *Engström* (1949) in particular. *Holmstrand* (1957) and others have used this and complementary biophysical techniques in detailed studies of mineralization in experimental bone grafts. Very few microradiographic papers have been published, however, concerning the effect of bone-grafting in man. The present paper is concerned with such cases, obtained and investigated in connection with operative treatment of pseudarthrosis.

MATERIAL AND METHODS

The clinical material comprised a total of 11 pseudarthroses on the ulna or radius. Resection of the pseudarthrosis was undertaken in 9 of these cases, the length of the resultant defect ranging from 1.8 to 3.5 cm. The defect was filled with an autogenous

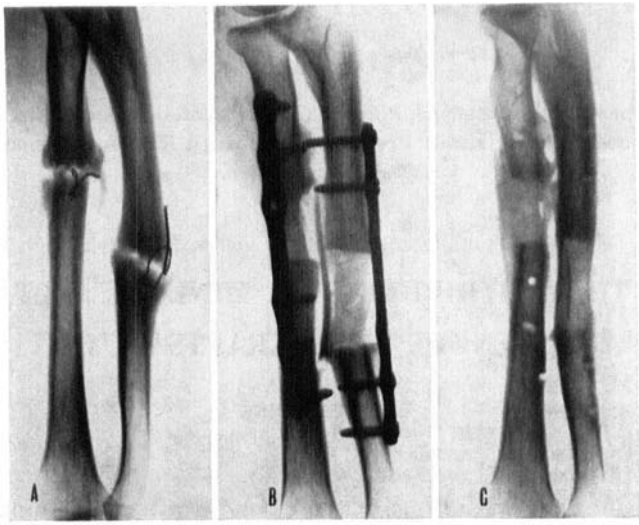

Figure 1. A. Non-union of the forearm 8 months after injury. B. Radical resection and internal fixation has been performed, the defects in the bones have been filled by cancellous bone blocks from the iliac crest. C. Metallic fixation has been removed 10 months after bone grafting.

graft consisting of a block of spongy bone taken from the iliac crest. Internal fixation was achieved with Lane's plate. The clinical effect of this surgical treatment has been reported by *Hiertonn & Nilsonne* (1962). The surgical technique is illustrated in Figure 1.

Bone samples were obtained from the region of the graft when the material used for osteosynthesis was removed at different intervals after clinical healing had been noted. Bone was obtained from 7 cases 10–19 months after the operation for pseudarthrosis. Samples were taken from points corresponding to the middle of the graft and the boundary between this and the host bone. The material was treated with the methods used by the author in microradiographic studies of fracture callus and pseudarthroses (*Nilsonne* 1959, 1961).

RESULTS

Ten months after the operation (Figure 2), the graft displays islands with a relatively high degree of mineralization. These areas lack structure and have a uniform appearance resembling necrosis. Most of the osteoid tissue, however, displays a low degree of mineralization and there are numerous resorption zones. The direction of the osteons varies and they seem to run both longitudinally and transversely. Their mineralization is predominantly low.

The picture is the same in principle in a specimen 15 months after

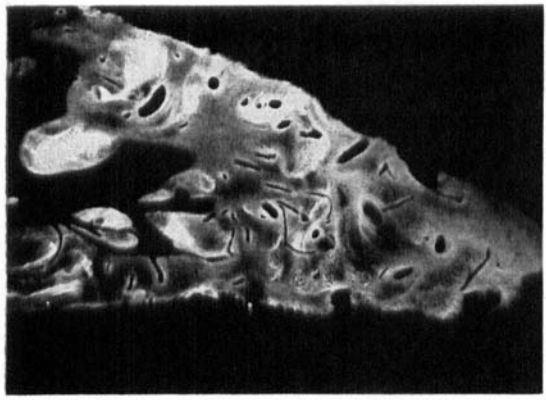

Figure 2. Longitudinal section from the middle of a graft 10 months after the transplantation.

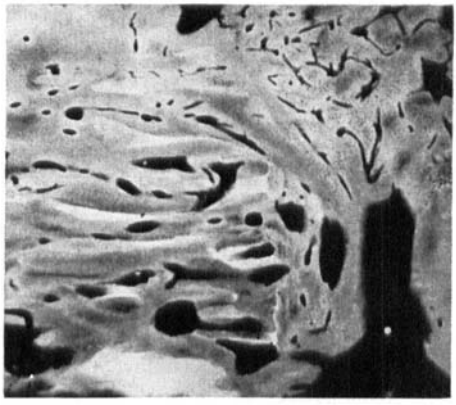

Figure 3. Longitudinal setction from the transitional zone between the graft (to the left) and the host bone (to the right) 15 months after the transplantation.

the transplantation (Figure 3). The homogeneous, mature distribution of bone salts in the host bone is clearly distinguishable from the more varied picture in the graft, with its lower average degree of mineralization. The graft still displays necrotic-looking islands with high mineralization and there are also several resorption cavities. The Haversian systems are tending to become more organized.

The principal features are still present in a specimen 19 months after the transplantation (Figure 4). There is, however, an increased reorganization of the graft region, which is being transformed into something like mature bone. There are only a few, small necrotic remains of the original graft. Mineralization is inhomogeneous but has increased somewhat in some Haversian systems compared with samples taken earlier. The resorption cavities are more numerous and larger.

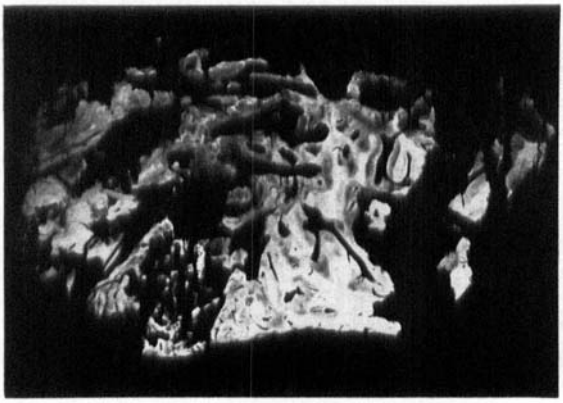

Figure 4. Longitudinal section from the middle of a graft 19 months after the transplantation.

DISCUSSION

A study of the distribution of mineral salts in healed bone grafts cannot of course be used to show whether the graft has taken an active part in the process of repair or simply been passively incorporated in a callus region. The microradiographic investigation does, however, indicate the degree to which bone salts are deposited and the correlation between this and the various morphological structures in the graft region. This makes it possible to relate the progress of re-organization to the process of healing.

Stringa & Mignani (1967) and *Cauchoix et al.* (1966) seem to be the only authors who have so far reported microradiographic investigations on bone grafts in man. At the same time, neither of their materials is fully comparable with the present one. In the former case, the graft consisted of cortical bone from the tibia, while in the latter the graft comprised both cortical and spongy bone and the operations were performed on growing individuals (fusion for scoliosis). In the present cases, the graft consisted of spongy bone only and the operations were performed on fully-grown individuals.

The remains of the original graft are a striking feature of the microradiographic pattern, still present more than a year after the transplantation as small, seemingly hypermineralized areas, with a devitalized appearance. The same observations have been reported by *Cauchoix et al.* and *Stringa & Mignani.* The latter authors estimated that the density of the bone—measured as X-ray absorption—was about 10 per cent greater in the graft than in the callus bed. Clearly, resorption is a slow process even in the case of an autogeneous bone graft. There is no well-

defined topographical line of resorption; instead, the process of mineralization corresponds to the histological pattern of creeping substitution.

The invasion of the graft by osteoid tissue can be studied in the arrangement of the Haversian canals. Even in late stages of healing, osteons with a highly varied degree of mineralization are to be found running both longitudinally and transversely. This suggests that vessels grow into the graft both from the host bone and from the surrounding soft tissues. Microangiographic studies (*Göthman* 1961) have shown that the soft-tissue reaction involves a lively formation of new vessels and the extension of vessels into the fracture callus. It therefore seems that the entire graft region should be regarded as a callus region in clinical autogeneous bone grafts on the present scale. Regardless of whether the graft does or does not develop an independent cellular activity, it thus lies between the ends of the pseudarthrosis in a tissue that is probably analogous with that in fracture callus.

As in the case of resorption, the reorganization and remineralization of the graft takes a long time. In this respect, however, there is a notable difference between the clinical development and the microscopic mineralization. In the present cases, full mechanical stability (*i.e.* clinical healing) was achieved within 3–7 months after the operation. Complete consolidation was also obtained within this interval according to the macroscopic X-ray examination. The microscopic pattern, however, indicates that the graft is still undergoing reorganization 19 months after the operation: numerous resorption zones as well as lamellar bone with a varying degree of mineralization. There is thus a notable dissimilarity between "clinical" and "biological" healing of an autogeneous bone graft. This agrees with observations from quantitative microradiography of experimental fracture callus (*Nilsonne* 1959) and experimental bone grafts (*Holmstrand* 1957).

SUMMARY

The distribution of mineral salts was investigated microradiographically in 7 cases of healed autogeneous bone grafts in man. The pattern of mineralization is described and discussed, with reference to the difference between clinical and biological healing.

RESUME

La distribution de sels minéraux a été étudiée microradiographiquement dans sept cas de greffes autogènes osseuses consolidées chez l'homme.

Une déscription générale de la minéralisation est donnée et discutée, soulignant la différence entre consolidation clinique et biologique.

ZUSAMMENFASSUNG

Die Verteilung von Mineralsalzen in geheilten autogenen Knochentransplantaten an 7 Patienten wurde mit Mikroradiographie untersucht. Die Art der Mineralisation und besonders die Unterschied zwischen klinischer und biologischer Heilung wird besprochen.

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